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HOW PARTS CONNECT TO WHOLE IN BUILDING DIGITAL GENERATIVITY IN DIGITAL PLATFORM ECOSYSTEMS

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Research in Progress

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Abstract

Generativity drives digital innovation and platform growth by engaging many other businesses with diverse digital skills and resources in a digital platform. As the proliferation of generativity research grows, the Information Systems (IS) literature demonstrates the basic understanding of this notion in the areas of properties of digital technologies, social events, and/or the interaction between these two without an integrated view of how generativity is raised to enable the digital innovation. Therefore, considering that digital platforms are a kind of ecosystem, we aim to develop a new understanding of this emerging phenomenon by employing a holistic perspective. Through the information ecology theoretical lens, we develop a digital generativity process model that explains how the technological and social resources interact to generate perpetual digital innovation in digital platform ecosystems (DPE). This study contributes to generativity research by providing a dynamic and holistic view of generativity formalization in DPEs.

Keywords: Generativity, Digital Platform Ecosystem, Tension Moderation, Process Model.

1 Introduction

Generativity, defined as a "system's overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences" (Zittrain, 2008, p. 80), is a driver of digital innovation in digital platform ecosystems (Yoo, 2012). In the context of DPE, information systems (IS) research captures generativity as a generative system comprising diverse actors, such as third-party complementors, producing unanticipated results (Eck and Uebernickel, 2016).

A DPE comprises a central digital platform facilitating value-creating activities between the actors, such as the platform owner, autonomous complementors, and customers (Hein et al., 2020). The system is generative as the ecosystem of actors reconfigures the social and technological resources to spur new digital innovation. Increasing the number of third-party complementors in DPEs results in more variety and digital applications, for instance, in the software development and digital service industry (Boudreau, 2012).

The existing literature on generativity is emerging yet fragmented. When generativity is examined, studies attribute innovative capacity primarily to social activities or technology separately. Some literature assumes that generativity arises from platform governance that can stimulate value-adding modules from complementors and bundle complementor-developed services with the digital platform (Foerderer et al., 2014; Tiwana et al., 2010). Literature from a technological perspective proposes that

generativity emanates from the layered modular structure of the platform architecture and the availability of standardized interfaces (Ghazawneh and Henfridsson, 2013; Sun et al., 2021; Um et al., 2013; Yoo et al., 2010). Several papers also investigate the interaction among interdependent actors jointly engaging in creating ideas (Elaluf-Calderwood et al., 2011; Foerderer et al., 2014) and complex entanglements between heterogeneous social and technological resources (Jarvenpaa and Standaert, 2018). These types of interactions result in generativity, the variance of generativity depends on the delicate balance and reconciliation of the tensions generated by the interaction process (Msiska and Nielsen, 2018).

The recent literature has attempted to shed further light, such as studies by Thomas and Tee (2022) and Sun et al. (2022). These two works contribute to the integrative views of generativity by deepening the understanding of the antecedents-processes-outcomes of generativity. Despite these advances, the question remains: *how does generativity occur in the DPE?*

The diverse perspectives on generativity research show a vague and un-unified understanding of forming generativity in DPEs for IS scholars. It is essential to consider the structural relationships of these constructs, e.g., platform governance, architecture, or interaction processes, in achieving generativity in DPEs because missing the specific understanding of the relationships hinders the further theorization of generativity (Doty and Glick, 1994; Gregor, 2006).

Generativity in DPEs is an evolving and multilevel phenomenon that is difficult to capture physically. This article aims to explain generativity in DPEs by investigating the part-whole relations through information ecology theory (Nardi and O'Day, 2000; Wang, 2021). Information ecology theory looks at the phenomenon from a part-whole perspective to explain how parts (e.g., digital technology, individuals, or organizations) form a whole (generativity of the digital innovation ecosystem) through the process. The multi-layered information ecology theory attempts to address the complex nature of digital innovation systems and the contribution of digital technology to them (Wang, 2021). Adopting the ecological concept of holon, digital innovation ecosystems are simultaneously the whole of many contributing parts and also acting as part of the greater whole (Gu et al., 2021). Loosely independent actors (individuals or organizations) interact and influence each other throughout multiple layers of digital platform ecosystems. Ecosystems then interact and influence each other to form more extraordinary ecosystems. Information ecology theory examines how, using digital technology, various actors of digital innovation ecosystems as the parts interact with each other within and across ecosystems, as well as up and down tiers of ecosystem levels called holarchies (Márton, 2021).

Drawing on information ecology theory, we explore how the interaction process between parts can be congruent to the rise of generativity in DPEs. To do so, we develop a process model of digital generativity in DPEs by analyzing the current literature on generativity and digital platforms.

Through our study, we show how social and technology interplay with each other to spur generativity. We extend information ecology theory by demonstrating the roles and impacts of tensions in the interaction process between actors and technology for digital innovation, whereas information ecology theory emphasizes the complexity of the innovation process.

2 Research Methodology - Systematic Literature Review

We aim to clear the prevailing concern around the occurrence of generativity by adapting the traditional systematic literature review (Webster and Watson, 2002). The literature review includes journals: the "Senior Scholars Basket of Eight Journals," Organization Science, and the high-quality proceedings of the International Conference on Information Systems, the European Conference on Information Systems, and the Haiwai Conference on Systems Sciences.

We searched for the keywords 'generativity' or 'generative capability' in the above outlets in four major bibliographic databases (JSTOR, EBSCO, Web of Science, and AISeL), for the period between 2006 and 2022. As a result, 192 articles were collected for further analysis. After scrutiny of each

article, 74 were removed, in which the term "generativity" was only mentioned briefly, and 77 duplicated articles were eliminated, leaving 41 articles for data analysis.

Our data analysis includes two steps, thematic analysis and data structure, as detailed below.

2.1 Step 1: Thematic Analysis

In order to understand the part-whole relations in the generativity formulation in DPEs, we first conducted a thematic analysis to group generativity research according to the focus of the research. As a result, we identified four research streams of generativity research in IS, shown in Table 1.

Technological Streams: Generativity arises due to the components of digital architecture.
1. Digital modular architectures facilitate generativity by allowing loose couplings between layers (Henfridsson et al., 2018; Yoo et al., 2010). 2. Boundary resources such as API and SDK determine the boundaries of an ecosystem, thus the generativity of the digital platform ecosystem (Hein et al., 2019; Nambisan et al., 2019). 3. Innovation in the pattern of combinations of APIs drives the generativity of the platform as value-adding activities continuously occur in the ecosystem over time (Fürstenau et al., 2019; Sun et al., 2021; Um et al., 2015). 4. The stable and extensible core of digital architecture serves as a foundational basis for the platform ecosystem and can be reprogrammed to accommodate evolving requirements (Um et al., 2013; Yoo, 2012).
Social Streams: The mutual relations among platform owners, complementors, and users shape generativity.
1. The platform owner provides the digital core and boundary resources to support the complementor innovation while maintaining a delicate balance of control (Bygstad, 2017; Foerderer et al., 2014). 2. One the DPE, heterogeneous complementors indirectly collaborate on the same system and differ significantly in various aspects, such as their levels of competence, social positions, and access to resources (Lane, 2011). 3. Autonomous complementors leverage their entrepreneurial instincts to creatively engage with technology to fulfill self-interests and ideas (Cennamo and Santaló, 2019; Nambisan et al., 2019).
Process Streams: Generativity emerges from the inherent tension embedded within the socio-technical characteristics of digital platforms.
1. Tension emerges from the social interaction, such as reputation spillover effect & free-rider effect (Cennamo and Santaló, 2019; Wang, 2021), social-technical interaction, such as flexibility & stability (Sun et al., 2021; Tilson et al., 2010) and control & autonomy (Foerderer et al., 2014). 2. The process of generating digital innovation remains open-ended as inputs are derived from heterogeneous actors, and diverse outputs serve as input resources for further innovation (Fürstenau et al., 2019; Jarvenpaa and Standaert, 2018).
Outcomes of Generativity： The impact of generativity
1. The generativity of DPEs represents the unanticipated outcomes (Cennamo & Santaló, 2019). 2. Those unimaginable outcomes further impact DPEs' value performance, for example, the emergence of new business models (Marheine and Pauli, 2020), new partner engagement (Brodie et al., 2011), evolution (Henfridsson and Bygstad, 2013), internet malware (Zittrain, 2008) and low usability (Nielsen and Hanseth, 2010)
Overall Views of Generativity in Literature
A systematic review and conceptual framework on generativity in the literature: Eck et al. (2015); Sun et al. (2022); Thomas and Tee (2022)

Table 1. Thematically grouped descriptions of factors in generativity literature

Through the analysis, we found the imbalance favoring the "parts" over the "whole" in current generativity studies. On the one hand, most of the studies are single-part focused research. Most papers examined the complex interplay between the digital platform and the control of platform

owners in DPEs to facilitate generativity while briefly considering other attributes of the ecosystem, like the role of different actors and their interplay with the digital platform (Thomas and Tee, 2022).

On the other hand, a few studies examined the whole digital platform ecosystem's generativity but focused on the single side of DPEs. For instance, the study focuses on the generativity of a technical-centric digital ecosystem, depicting the structural patterns of how individual modules interact through the boundary resources, such as APIs and SDKs, without considering social elements (Karhu et al., 2018). APIs created by the focal firm and the external APIs developed by the other complementors shape the architecture of the generativity of its ecosystems (Um et al., 2013). The study depicts the generativity of a social-heterogeneity digital ecosystem, presenting the cooperative relationship between a set of heterogeneous actors to drive the generative potential of DPEs without considering technological factor (Foerderer et al., 2014). The recent study advanced the research by arguing that combinatorial innovation is generated when there is an alignment between the generative potential of digital architecture and social actors (Thomas and Tee, 2022). However, this study is with little exploration on the process to achieve that alignment.

Solving the part-whole imbalance problem would require theorizing beyond the scope of the current literature. Next, we map the general Information ecology theory concepts to generativity in DPEs.

2.2 Step 2: Data Structure

We followed the grounded theory method by Gioia et al. (2013) to analyze data, shown in Figure 1. To explore how the parts interact with each other to form the whole, we carefully coded the full text of the articles. We annotated specific part-whole interactions (first-order categories) among the parts.

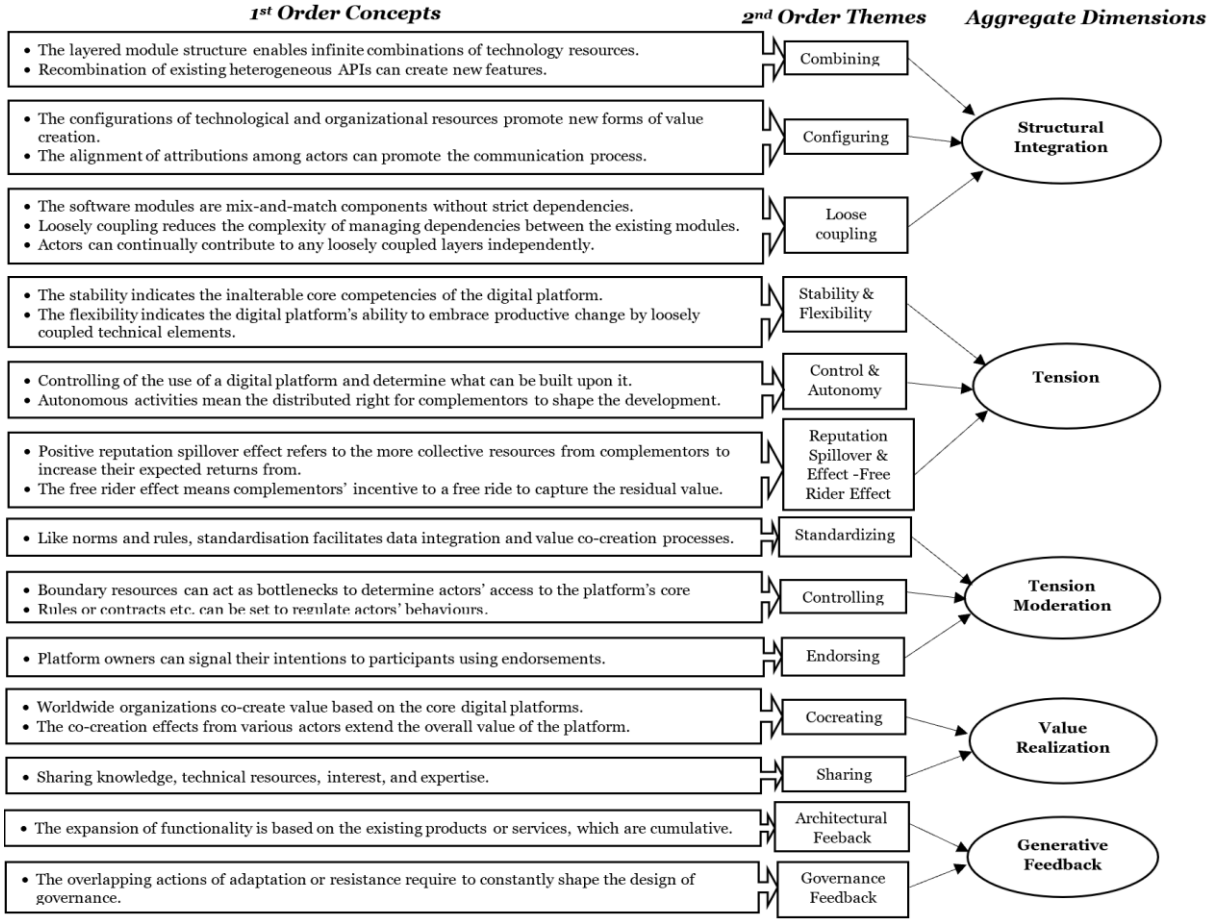

Figure 1. Data structure.

Based on the commonalities of the interactions, we grouped 1st order concepts into 13 categories of themes (2nd order themes) and further refined them into five aggregate dimensions.

3 Findings

Based on our data analysis, we present our process model that depicts the parts of generativity and the interactive digital innovation process (shown in Figure 2). Within DPEs, digital innovation may manifest as a pattern of actions or interactions and performance resulting from the innovation at the levels of both the parts and the whole (Wang, 2021). Regarding innovation pattern, at the level of **Parts**, we propose that the interaction process for generativity stems from the ***Structural Integration*** of technological and organizational resources from heterogeneous actors. Such structural integration explains the innovation process: *Combining, Configuring, and Loose Coupling* (depicted in Figure 1), where ***Tensions*** emerge as the inherent nature of **the Part-Whole Relation** toward generativity (Tilson et al., 2010). Innovation processes in DPEs can lead to greater generativity, resulting in unintended and potential applications that ultimately increase value for end-users. Generativity can also lead to a fragmented system that may negatively impact user satisfaction and the overall market performance of the platform system (Tiwana, 2015). The inherent tensions spurred by the interaction between heterogeneous complementors would be either drivers or hindrances of the generativity depending on the dialectic moderation (Lehmann et al., 2022).

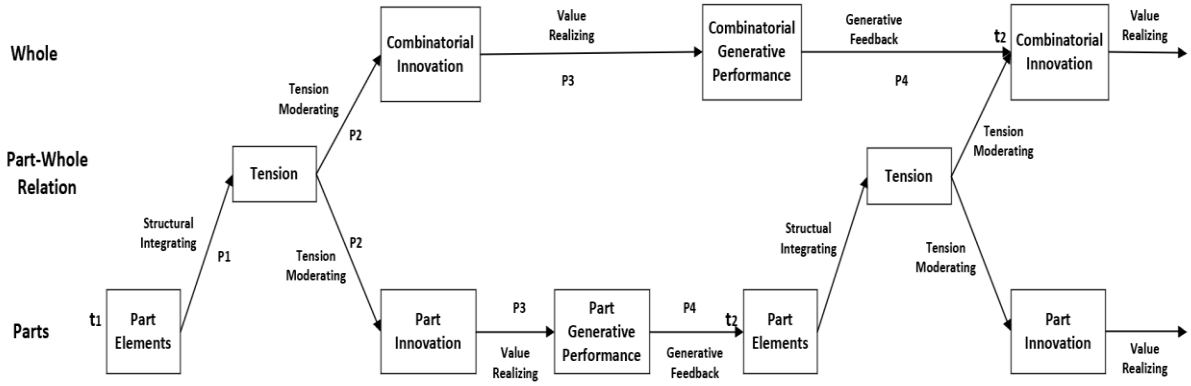

Figure 2. Interaction process to form generativity in DPEs.

Tension Moderation is the management strategy that stimulates the desired generativity variance and creates part and combinatorial DPE innovation by *Standardizing*, *Controlling,* and *Endorsing* (Staub et al., 2022). Regarding innovation outcome, innovation at the **Part** level is perceived as significant changes on the part of the modules of the service, products, or business models due to the actors' pursuit of their interest (Fichman et al., 2014). Combinatorial innovation at the **Whole** level is considered the nearly infinite recombination or integration of existing technological modules (Yoo et al., 2012). Combinatorial innovations often involve designing modules without the intended purpose of how each module will be integrated with others (Gawer, 2014). With combinatorial innovations, the boundary of a generative system is unanticipated and incomplete (Yoo et al., 2010).

At the **Part** level, innovation performance is the outcome of the actors' pursuit of the innovation's intrinsic value for its own goal. Each actor's engagement with the innovation is conducive to realizing the extrinsic value for the ecosystem innovation as a whole, thus attracting more actors to join the innovation process (Wang, 2021). The **Part** generative performance may show as the modules being more complementary to the multisided market (Ciriello et al., 2018). The **Whole** combinatorial generative performance manifests as the DPE's evolution with the increasing scale and scope (Bygstad, 2017). The generative performances are realized through *Value-Cocreating* and *Sharing.* Generative performances further enable the ***Generative Feedback*** process, continuously adapting the part-whole relations and the actors' value and motivation to participate in the ecosystem. Part-whole

relationships exist throughout multiple loops of the relationship model. The relationship formed in Time one (t_1) carries over to the next loop, Time two (t_2), and the whole of t_1 can be part of t_2, and vice versa, through the infinite number of continuing loops.

The performances at the **Part** level may indirectly shape the **Whole** ecosystem's overall performance. Based on the **Part** performance, an actor may adapt his participation in the innovation. Its adapted innovation activities may alter the innovation as a **Whole** and the overall ecosystem performance (Wang, 2021). Through such adaptation, generative feedback stimulates further part integration and tension-moderated innovation, thus creating an ongoing loop of the evolution of digital innovation. More details will be further explored below.

To start with, ***Structural Integration*** relies on the *Combination* of mixing components belonging to several actors to create something new (van Osch and Avital, 2010). Generativity in a platform is realized by combining the existing and programmable modules from different actors with different toolsets and methodologies. The inventive recombination of existing modules accelerates the breeding speed of new functionalities in DPEs, resulting in an infinite product variation. Moreover, rich combinations of APIs also attract more heterogeneous complementors because the new combination creates new features that attract complementors with special skills (Jarvenpaa and Standaert, 2018).

The consistent *Configuration* of the technological and social resources makes the DPE malleable to spur complementor engagement (van Osch and Avital, 2010). The complementor engagement is a critical success factor for the generativity in DPEs because the quantity of products or services generated depends on the complementors' input of value-adding complementarities (Jacobides et al., 2018). The technological resources comprise a modular core, standardized interface, and complementary extensions (Karhu et al., 2018). The social resources mainly refer to governance mechanisms that distribute the control points among the complementors whose interests are aligned with the platform's value proposition (Nambisan et al., 2017). Then, the complementor engagement is afforded by an architecture that enables complementors to implement their extensions, thus supporting generativity independently. An architecture with common interface specificity accommodates incumbent complementors' specific needs, increasing complementor engagement.

Generativity is greatly supported by the *Loosely Coupled* layers of digital artifacts in the layered module architecture. Changes can happen in one layer without affecting other layers' operations (Henfridsson et al., 2018). These loosely coupled layers encourage more complementors to continually contribute to the focal platform because of the reduced efforts in managing dependencies with other modules in other layers. More external complementors are brought into the design and production of devices, networks, services, or content at different layers. Thus, the innovation of DPEs is product-agnostic, constantly surprising the original artifact designers. The innovation activities at different layers reciprocally and recursively influence each other leading to cascading effects on other layers (Adomavicius et al., 2008) and creating the image of "wakes of innovation" (Boland Jr et al., 2007). Thus, we propose,

Proposition 1: In DPEs, generativity as a whole can be achieved through the integration of components through the use of combination, configuration, and loose coupling.

Tension emerges from social-technological interaction. Generativity denotes change but also critically relies on stable foundations for change. Accordingly, generativity arises from the paradox of restricting access to core resources and granting access to core resources (Mini and Widjaja, 2019; Sun et al., 2021). It is a paradox of *Stability and Flexibility*. The DPEs should be stable to allow enrolments of new digital artifacts and maintain the integrity of digital platforms. In contrast, it is flexible to embrace various value-adding activities to contribute to the platform (Tilson et al., 2010).

Tension also arises from the social actors' interaction. On the one hand, the opposing logic around *centralized Control and individual Autonomy* is essential in navigating the paradox of stability and flexibility. More control set by the platform owners discourages further innovation, whereas more autonomous rights for complementors may allow low-quality applications, leading to deterioration in

DPEs' reputation (Eaton et al., 2011). For another, generativity creates the tension of the *Reputation spillover effect and Free-rider effect* among the complementors who feed on each other's contribution. At the same time, they compete simultaneously at the individual level to capture the majority of the cocreated value (Cennamo and Santaló, 2019). The extent to which generativity enhances value creation to the DPE relies on the collective's response to these tensions (Faraj et al., 2011).

The core challenge of generativity in DPEs is continuous ***Tension Moderation***. The dialectic resolution of the emerging tensions leads to unexpected yet innovative outcomes (Staub et al., 2022). The analysis found three actions in which the platform owner takes the role of moderating tensions. First, *Standardization* navigates the paradox of stability and flexibility by establishing a framework that standardizes the innovation process. For example, the external complementors of the on-promise apps for Oracle faithfully followed the standardized connection protocols to format, import, and export data files (Sun et al., 2021). All the modules are being integrated through standardization so that they are integrated using simple, standardized data transfers while under control.

Second, *Controlling* helps to balance the paradox of stability and flexibility. In order to control the input and process of the digital innovation process and address the negative consequences of flexibility, such as subpar performance and opportunistic behavior (Cennamo and Santaló, 2019), control actions have been put in place (Foerderer et al., 2014; Ghazawneh and Henfridsson, 2013). In input controlling, boundary resources act as bottlenecks allowing platform owners to permit or prohibit actors access to the platforms' core resource (Ghazawneh and Henfridsson, 2013). The compatibility between value-adding applications and the platform's core resources is a genuine concern when the complementors' access to the platform's core resources increases. Exercising control over boundary resources can extensively widen the scope of value-adding activities without jeopardizing the platform's core stability (Hein et al., 2019). In comparison, the process controlling involves the platform owners establishing guidelines for actors' actions on digital platforms through contracts or a protocol to grant authorized actors access to certain platform resources (da Rocha and Pollock, 2019).

Platform owners use *Endorsements* as signals to point out areas where generativity is desired at a particular stage in the growth of DPEs (Hukal, 2018). Platform owners would make tactical decisions to lessen the information asymmetry and encourage complementors to try more creative ideas in areas where generativity is required (da Rocha and Pollock, 2019). Thus, complementors are more likely to have optimistic expectations for their contributions to DPEs' value performance when they comprehend the platform owners' intentions (Lyytinen et al., 2017). Accordingly, we propose,

Proposition 2: In DPEs, the tension constitutes the essence of generativity, and the moderation of tension is to make generativity an ongoing process.

The overall platform ***Value*** proposition is ***Realized*** from the *Cocreated* effort jointly by the actors who pursue intrinsic values for themselves (Hein et al., 2019). Digital platforms allow actors to take advantage of network externalities, where actors provide the majority of complementary products or services (Hein et al. 2019b). Platform innovation is open to collaborative networks from interconnected complementors regarding the employment of resources and capabilities. The complementarity between individuals and organizations can satisfy customer needs in multisided markets and thereby extend the overall value of the digital platforms, thus leading to the DPEs' evolution (Foerderer et al. 2014).

The emergence of digital innovation stems from *Sharing* of knowledge among the actors, such as software code, the platform's source code, or the algorithm (Wang, 2021). The information exchange facilitates shared cognition among autonomous actors with diverse interests and norms. The mutual sensemaking of the context can overcome the stickiness of knowledge, and communication enables various outputs and opens new worlds of digital innovation (Lyytinen et al., 2016). The performance of generativity not only represents the different values pursued by the actors but also reflects specific common values shared by the participants. Therefore, we propose,

Proposition 3: The performance of generativity as a whole depends on the value it realizes from the innovation through co-creating and sharing value with other actors.

We have discussed that the performance of the part innovation or the combinatorial innovation relates to each other. Based on the performance, the parts may adapt their innovation activities depending on the ***Generativity Feedback*** gathered from the process of combinatorial innovation and generative outcomes--*Architectural feedback* and *Governance feedback*. By expanding functionality to extend the range of innovation, the architectural feedback process increases the artifact's generative potential. It explains how generative artifacts develop over time (Mønsted et al., 2020). The governance feedback provides inputs that stimulate the development of "new configurations and possibilities" through continual transformative processes, such as governance and boundary resource adaptation (Avital and Te'Eni, 2009; Thomas and Tee, 2022, p. 1). In all, the generative feedback indicates that the outcome of the generative performance may spur the evolution of DPEs in unexpected and serendipitous ways. Lastly, we propose,

Proposition 4: The generativity of DPEs is an open-ended process that stimulates turbulent, self-propagated, and diverse innovation through the gathering of architecture feedback and governance feedback.

4 Discussion and Conclusion

This study set out to explain how generativity occurs in DPEs through the entanglement between heterogeneous social and technological resources. These two parts in DPEs interact, expanding the possible outcomes. The unanticipated outputs from the generative system are turned into resources at the part level to create digital innovation at the whole level, and allow for further possibilities. This paper provides a starting point for understanding the generativity formulation in IS from the process perspective, which is important given the rapid socio-technological changes. Our process model explains how digital components interact with others across different functional groups to create new digital products driven by generativity.

We make the following theoretical contribution. First, we propose a process model of generativity in DPEs, which explains how the parts interact to form generativity. The process model shows the patterns in events and activities over time, which explains how DPEs change over time and what the sequences of events contribute to the system's generative evolution (Langley, 2009). Our process model paves the way for a future empirical study to develop a contextualized theory. Second, our process model adds new knowledge to the existing studies that mainly examine the nature of the generativity phenomenon in a single ecosystem and can inspire multilevel studies of generativity. As the concept of part-whole relations from information ecology theory indicates us every actor or technological piece is a part. Generative innovation outcomes can be both a part and a whole in the entire innovation process in DPEs. Generative innovation outcome is a whole, while it is the result of the interaction between parts, and is a part when forming a whole with other parts in the innovation process. Third, our study contributes to information ecology theory by demonstrating the roles and impacts of tensions on the interaction of actors and technology, which results in the expansion and reproduction of the ecosystem. Our findings can serve practitioners who need to become more familiar with the innovation capability to quickly grasp the technological and organizational factors that influence digital innovation and make strategic decisions on the series of activities to capture higher business value.

In the next step of our research, we will focus on conceptualizing the multilevel phenomenon to define generativity within the process view, especially conceptualizing how generativity can arise from multilevel cross-ecosystem interactions. We will study how the roles of specific actors (such as users, politicians, or generative entrepreneurs) and their alignment structures enable generativity and the role of alignment between generative architectures and generative actors to achieve the system's generative fit. In addition, we will conduct applicability checks, in terms of importance, accessibility, and suitability, with practitioners on the process model by Rosemann and Vessey (2008).

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